



Loran-C As A Secondary Navaid To Complement GPS

Patrick Y. Hwang, Rockwell Collins Inc.

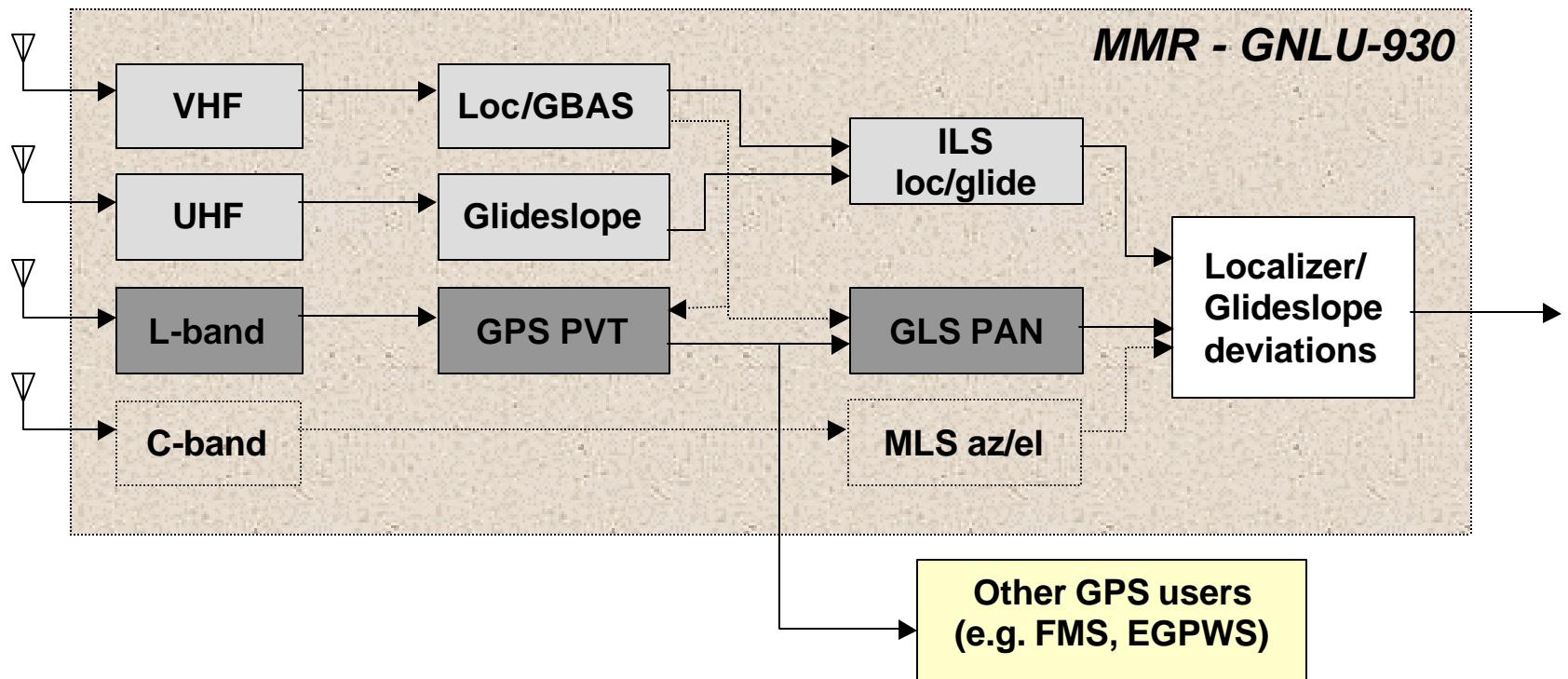
Robert N. Snow, Boeing Company

G. Linn Roth, Locus Inc.

Mitchell J. Narins, Federal Aviation Administration

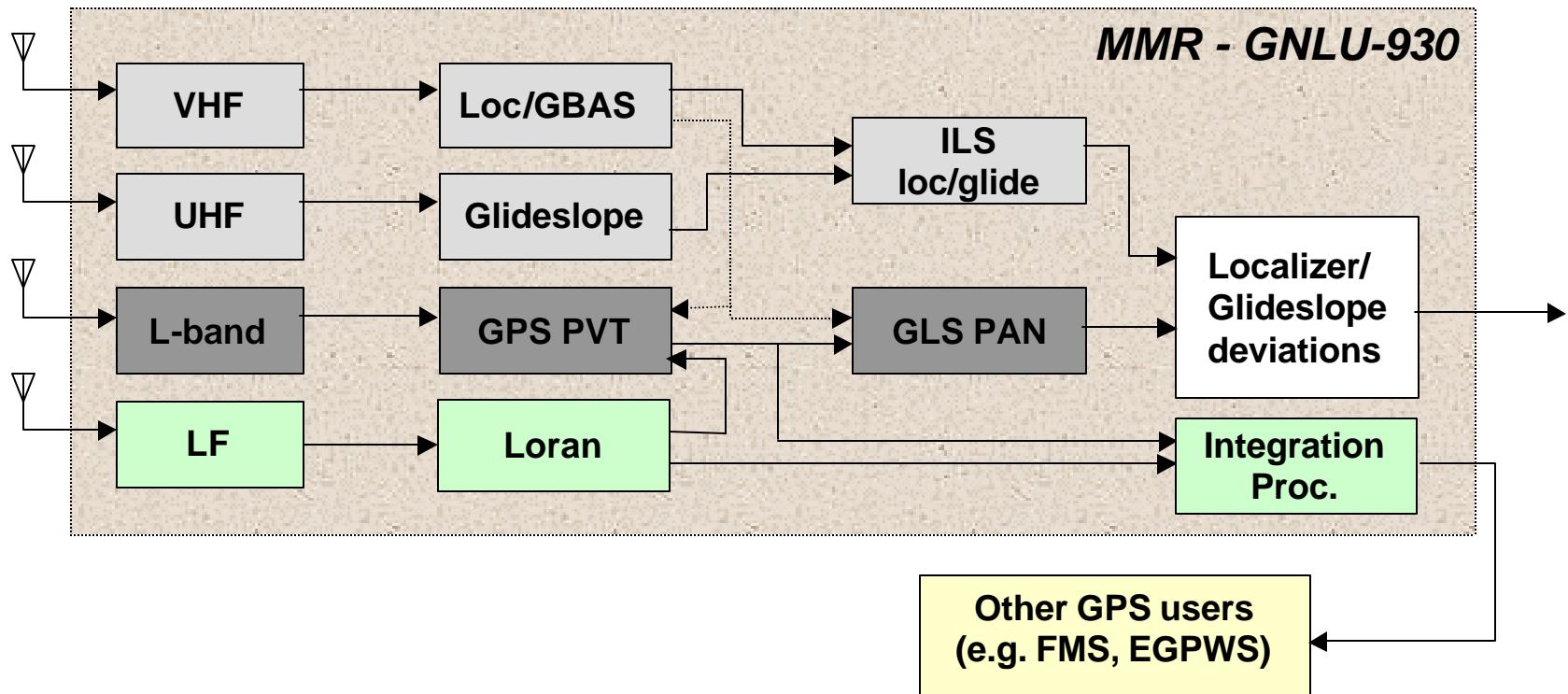
May 1, 2002

Current MMR



- FAA currently funding WAAS development in GPS PVT block of Rockwell Collins MMR
- MLS slice currently vacant

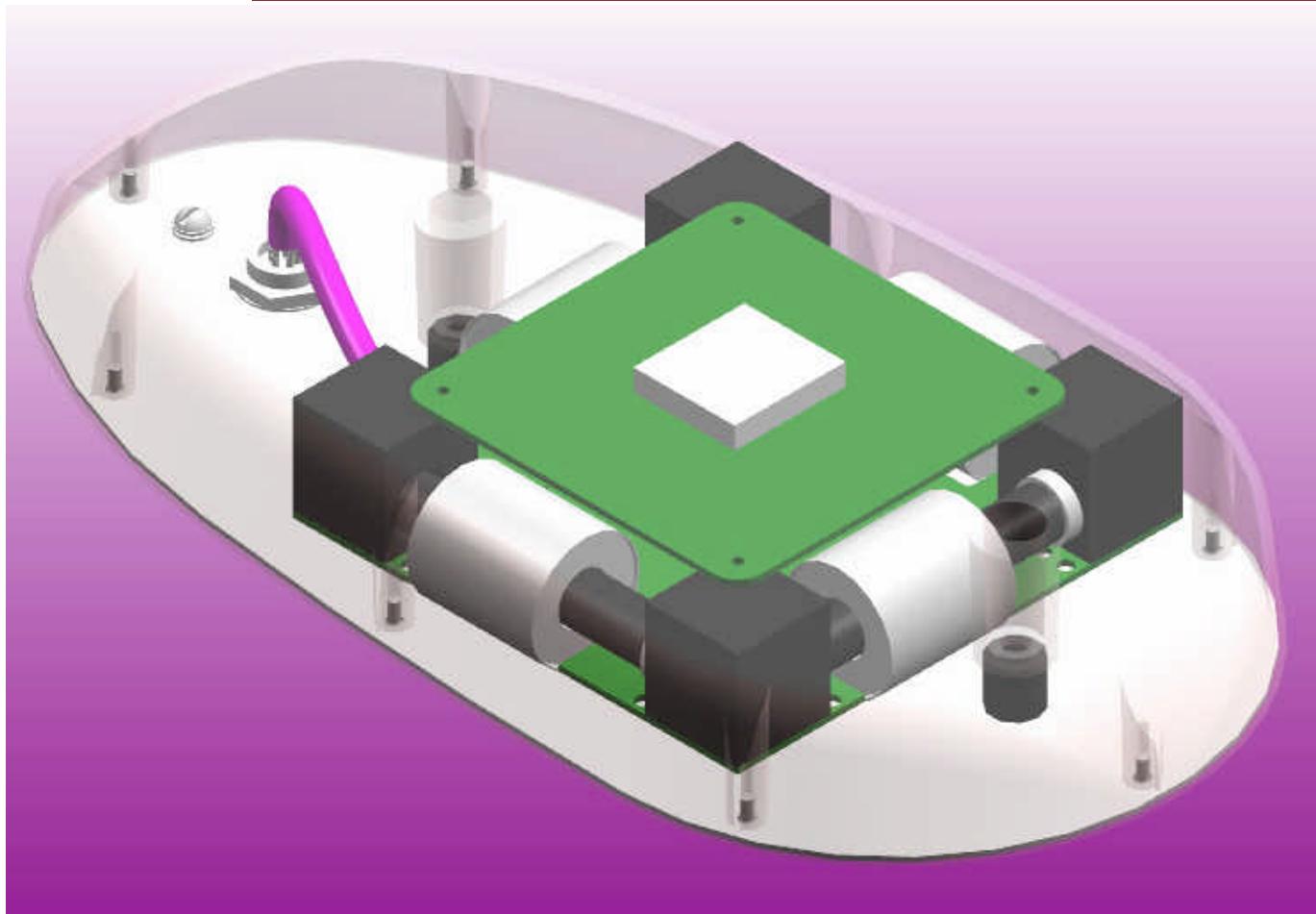
Prototype MMR For FAA GPS/Loran



- Integrated GPS/Loran prototype to be developed in another FAA program will utilize an independent Integration Processor
- Locus-developed Loran card embedded into Rockwell Collins MMR
- WAAS message data demodulated in Loran feeds into GPS



Combined GPS/Loran Antenna



Loran H-field ~ 130mm x 130mm x 50 mm
GPS microstrip patch



Potential Future Loran

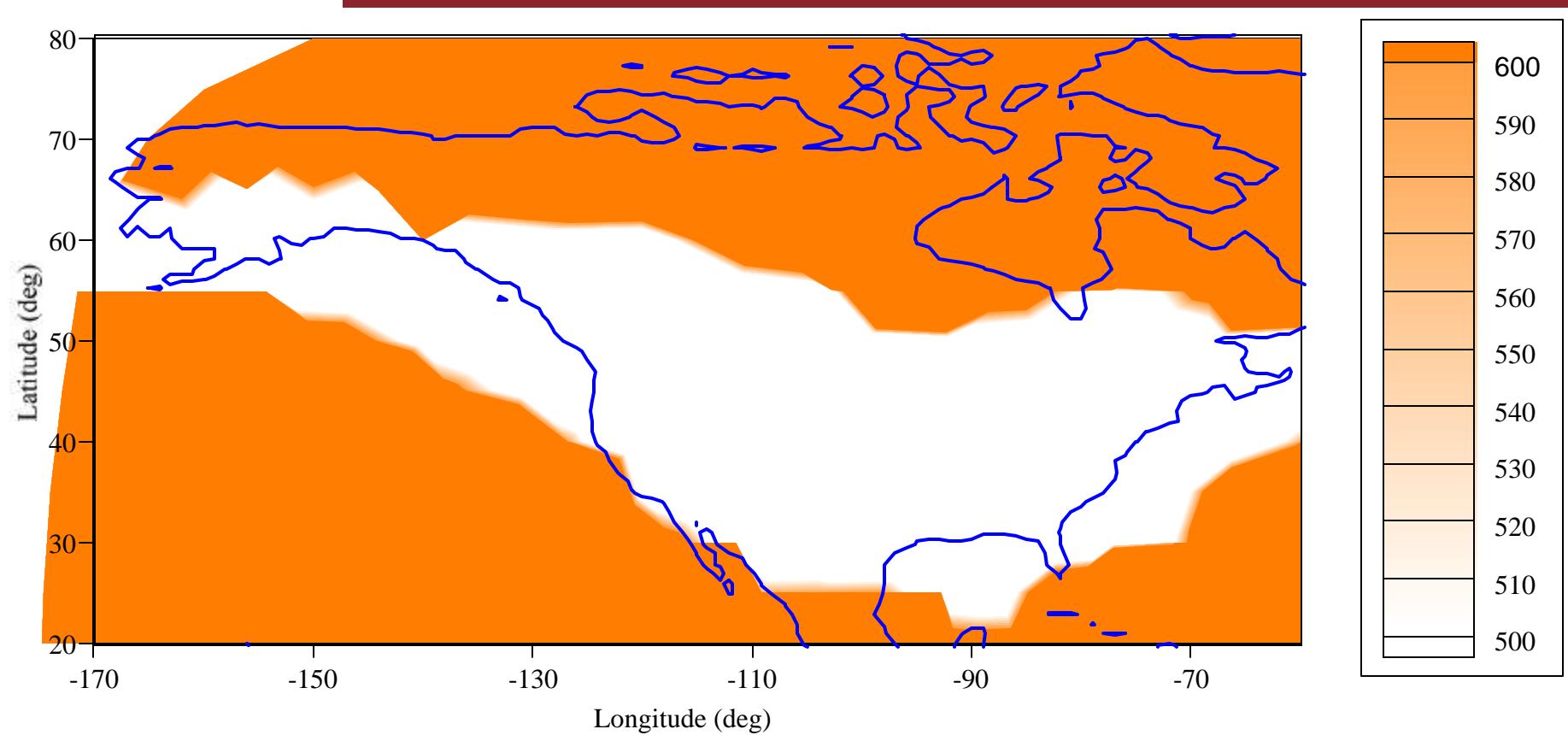
- One Continuous System
 - Navigation no longer based on use of stations in a single chain
- All Transmitters controlled to 50 nanoseconds of UTC (or better!)
- Time of Emission and better ASFs vs. Site Monitor Control
- DSP Receiver Technology
 - Time Of Arrival, All in View Processing
 - 20% More Range
 - 100 meter Range Accuracy (95% Confidence)
 - Earth Conductivity Corrections (ASF) Included



How Loran Can Complement GPS

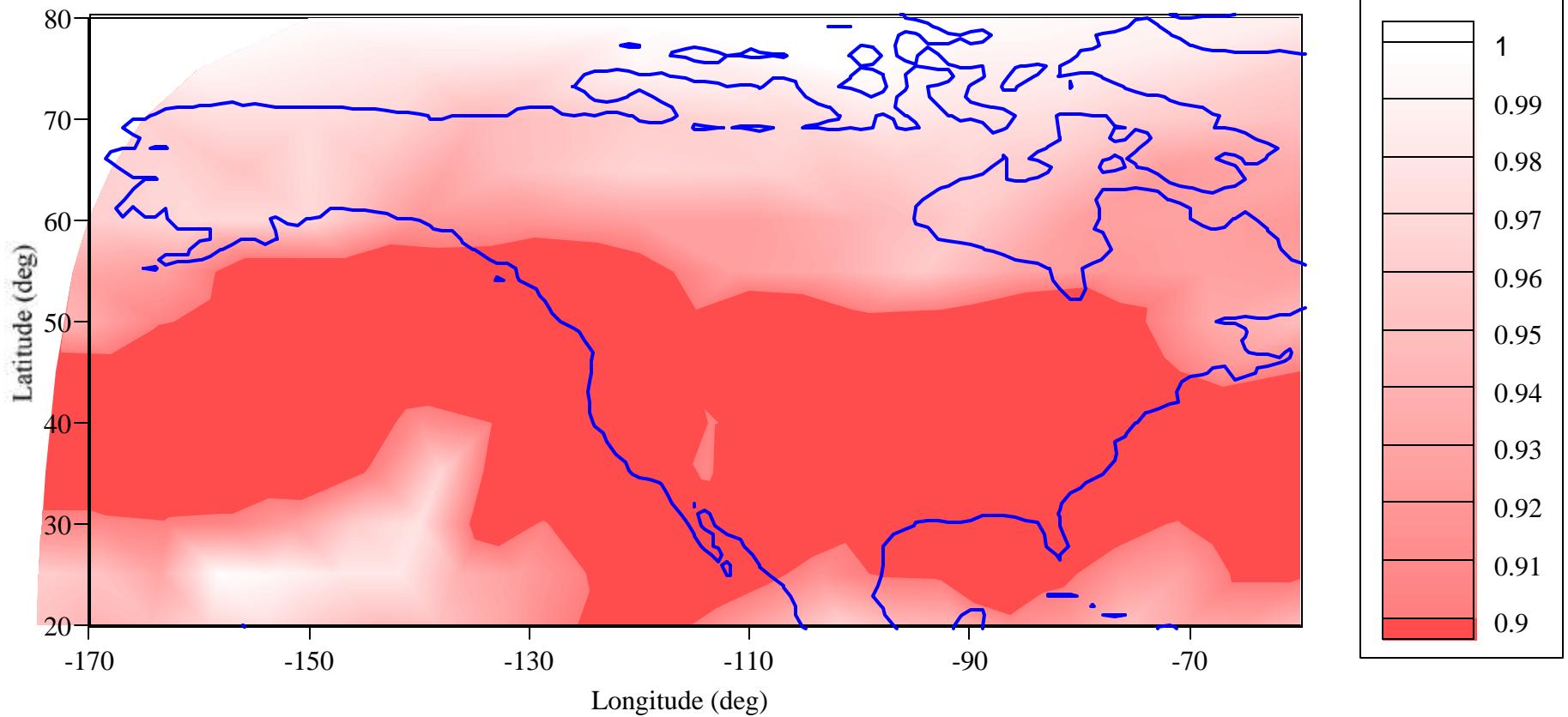
Modes	Integrity Assurance	Continuity of Function
Loran Ranging	<p>Loran ranging measurements used to improve GPS integrity monitor availability</p> <ul style="list-style-type: none">• by integration• by loose combination	<ul style="list-style-type: none">• Loran provides independent backup to GPS in the event of GPS outage for RNP 0.3• For $RNP < 0.3$, need for calibration of Loran biases with GPS, and coasting on Loran during GPS outage
Loran Data Channel	<p>Redundant access to WAAS integrity message to enhance GPS integrity performance in cases of total GEO outage</p>	<p>Redundant access to WAAS differential message in cases of GEO outage</p>

Loran-Only Error Bound (4σ)



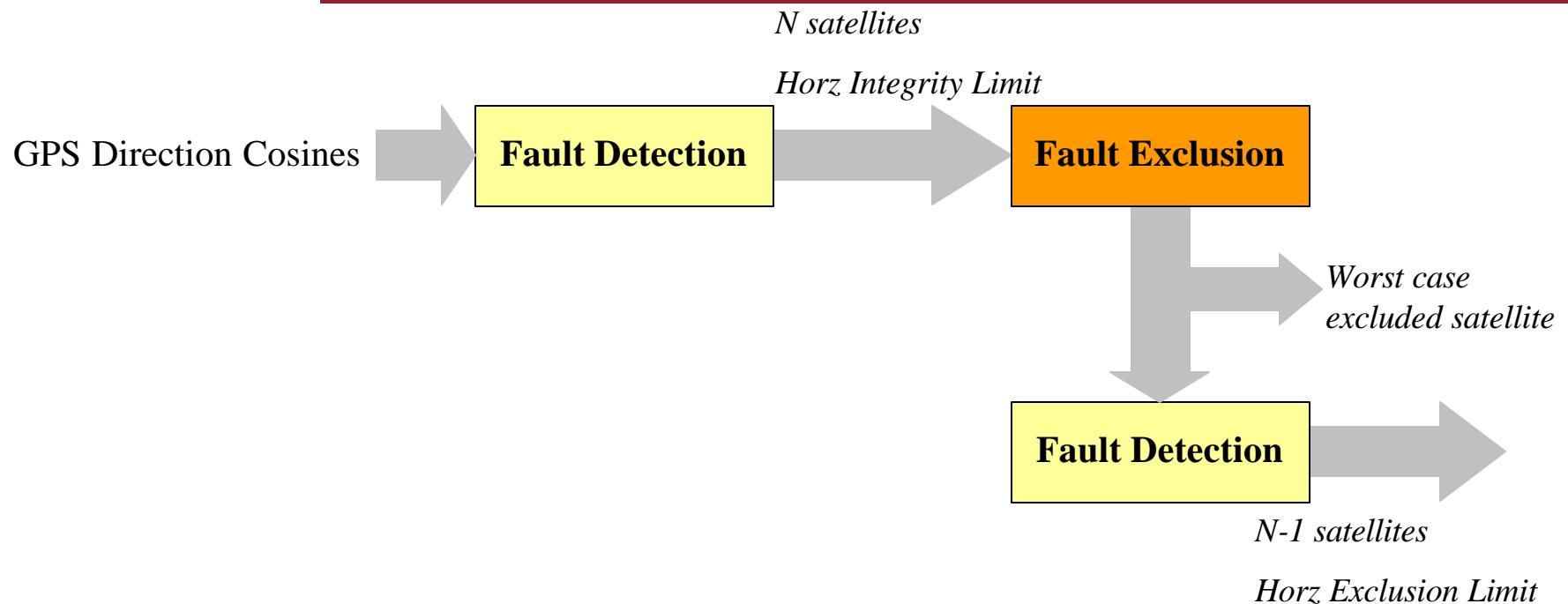
- Loran operating range ~ 1000 miles; range error (σ) ~ 50 m
- Loran is “available” if 4σ solution error is less than 555 m (0.3 nmi) to meet RNP containment requirements

RAIM Fault Detection & Exclusion (FDE) Availability - GPS-Only



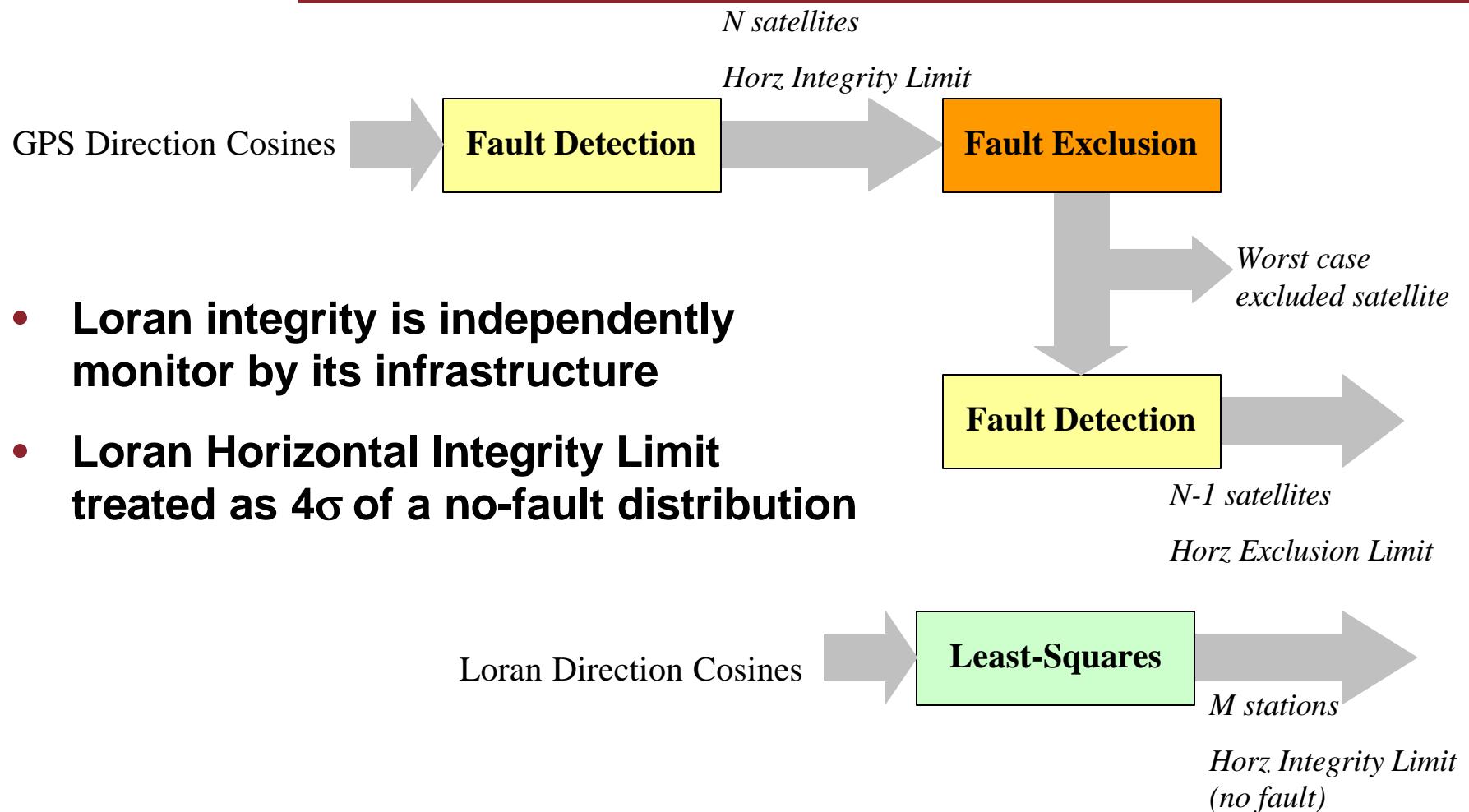
- **24-satellite GPS constellation**
- **GPS error (σ) ~ 12 m**
- **Availability criterion (for non-precision approach) ~ 0.3 nmi or 555 m**

GPS-Only RAIM-FDE

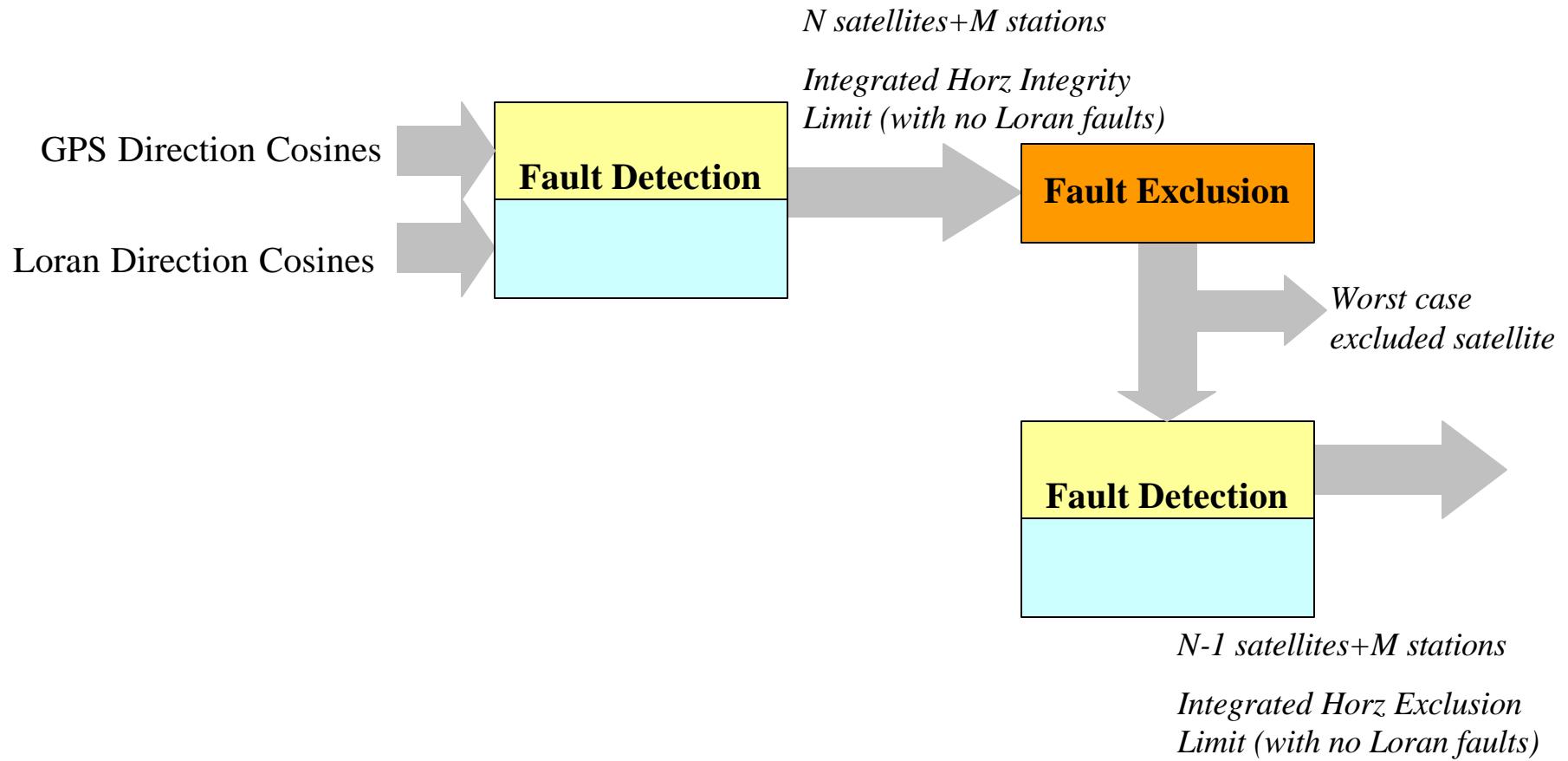


- Standard procedure for assessing RAIM-FDE availability

Combined GPS/Loran RAIM-FDE



Integrated GPS/Loran RAIM-FDE



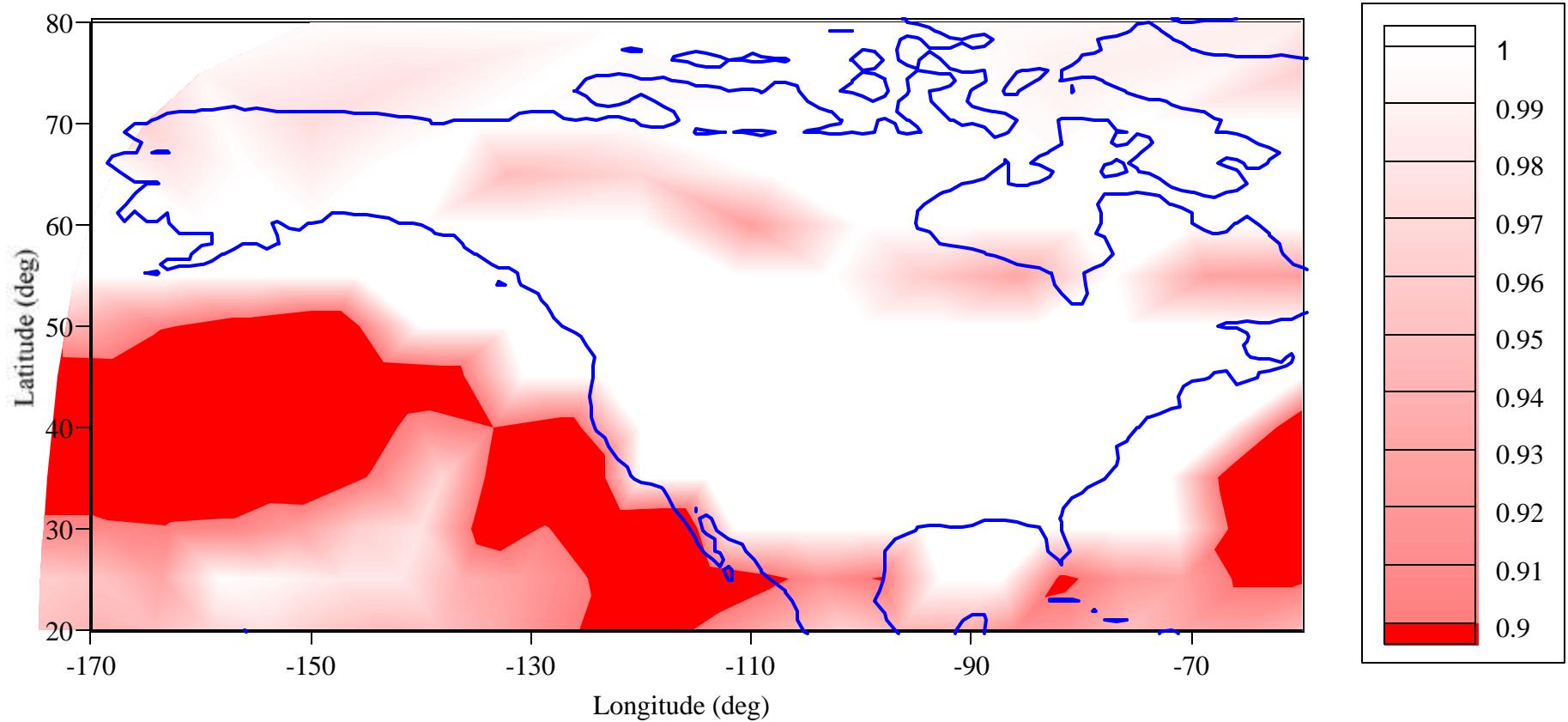
**Rockwell
Collins**

 **LOCUS**



 **BOEING**

RAIM-FDE Availability - Combined GPS/Loran

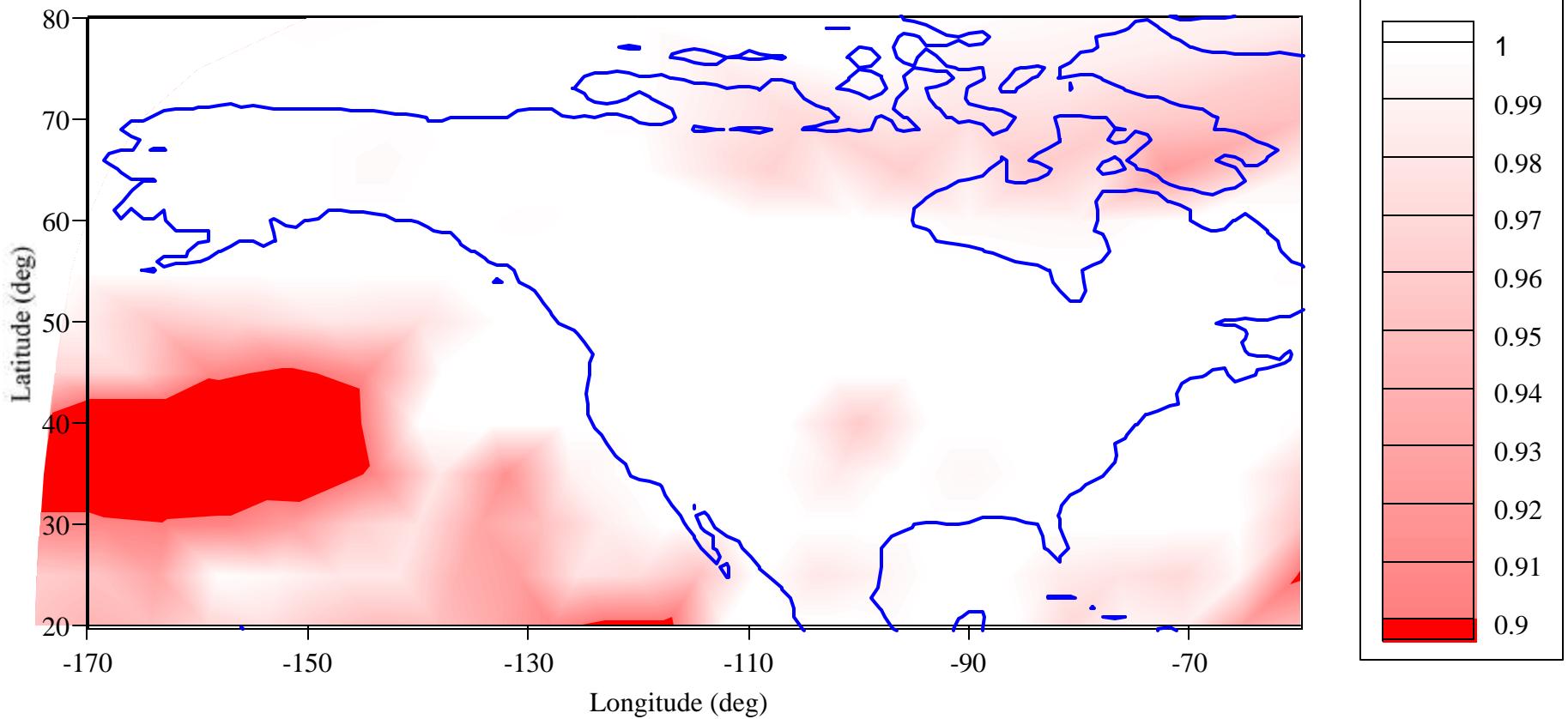


- Availability for NPA vastly improved in areas with Loran coverage

**Rockwell
Collins**



RAIM-FDE Availability - Integrated GPS/Loran

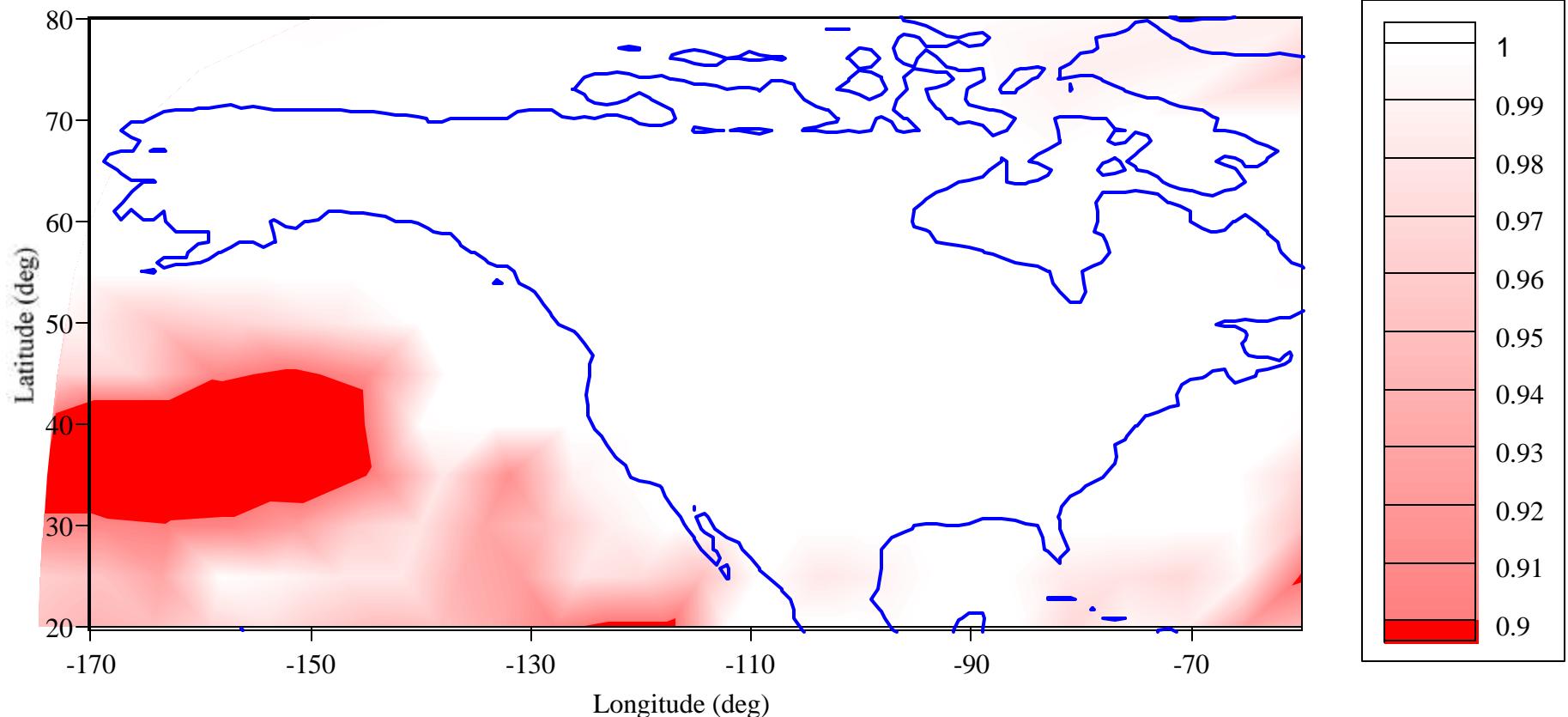


-
-

**Rockwell
Collins**



RAIM-FDE Availability - Integrated and Combined GPS/Loran



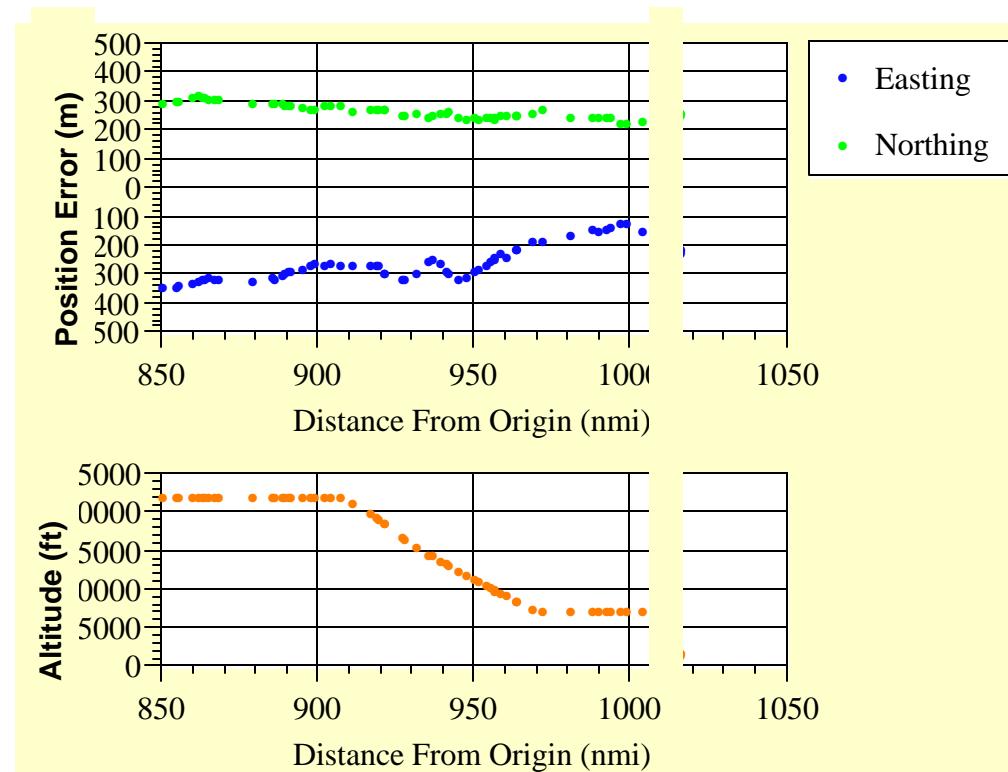
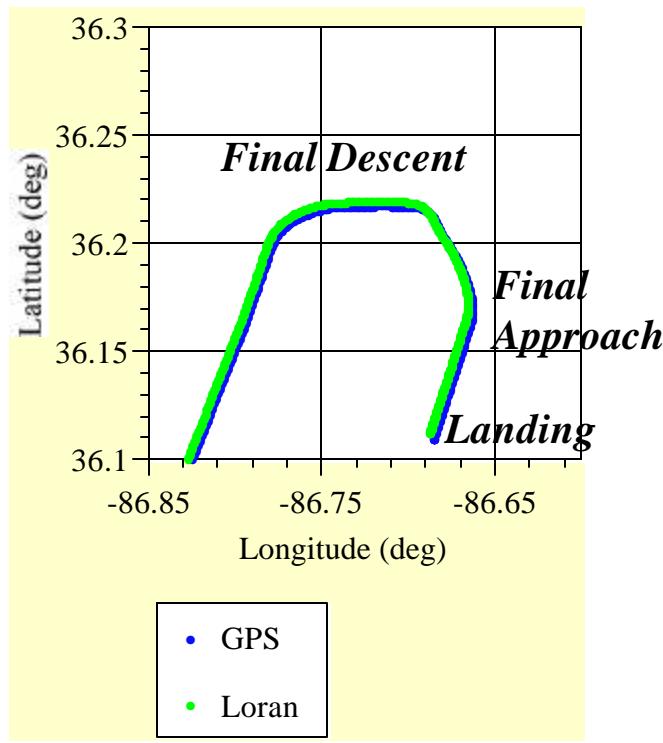
-
-



Closing Remarks

- **Preliminary Observations**
 - Loran can complement GPS by providing additional ranging information for integrity and continuity of function
 - Loran broadcast of WAAS data provides enhanced robustness to an already high integrity system
- **Further Study**
 - Quantify capability of Loran to augment WAAS coverage
 - Refinement of Loran error models with ASF corrections
 - Refinement of availability study to properly account for operational range based on transmitting power and terrain
- **Integrated GPS/Loran prototype development**
 - FAA's investigations include demonstrating feasibility of an integrated sensor

Loran Signal Stability



- Data for approach into Nashville, TN
- Loran “error” exhibits shift in descent - small for NPA; large for PA
- ASF corrections modeled for terminal area may mitigate this instability

**Rockwell
Collins**

 **LOCUS**



 **BOEING** ©



Questions